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Application No.	S2003/0235
Date of Filing	31 March 2003
Applicant	CORVIL NETWORKS LIMITED, an Irish company of Enterprise Centre, Pearse Street, Dublin 2, Ireland.

Dated this 8 day of April 2004.

An officer authorised by the
Controller of Patents, Designs and Trademarks.

FORM NO. 1

Application No. S 030235

REQUEST FOR THE GRANT OF A PATENT

PATENTS ACT 1992

The Applicant(s) named herein hereby request(s)
[ ] the grant of a patent under Part II of the Act
[X] the grant of a short-term patent under Part III of the Act
on the basis of the information furnished hereunder.

1. Applicant(s)

CORVIL NETWORKS LIMITED,
Enterprise Centre
Pearse Street
Dublin 2
Ireland
an Irish Company

2. Title of Invention
A method and system for quality of service optimisation in a data network

3. Declaration of Priority on basis of previously filed application(s) for same invention (Sections 25 & 26)

Previous Filing Date	Country in or for which filed	Filing No.

4. Identification of Inventor(s)

Name(s) and address(e) of person(s) believed by the Applicant(s) to be the inventor(s)
To follow

5. Statement of right to be granted a patent (Section 17(2) (b))

To follow

6. Items accompanying this Request

S030235

(i) [X] prescribed filing fee (Euro 60.00)
(ii) [X] specification containing a description and claims
[ ] specification containing a description only
[X] Drawings referred to in description or claims
(iii) [ ] An abstract
(iv) [ ] Copy of previous application(s) whose priority is claimed
(v) [ ] Translation of previous application whose priority is claimed
(vi) [X] Authorisation of Agent (this may be given at 8 below if this Request is signed by the Applicant(s))

7. Divisional Application(s)

The following information is applicable to the present application which is made under Section 24 -

Earlier Application No.
Filing Date:

8. Agent

The following is authorised to act as agent in all proceedings connected with the obtaining of a patent to which this request relates and in relation to any patent granted -

Name & Address

Cruickshank & Co. at their address recorded for the time being in the Register of Patent Agents is hereby appointed Agents and address for service, presently 1 Holles Street, Dublin 2.

9. Address for service (if different from that at 8)

Signed Cruickshank & Co.

By:- C. Schutt   Executive.

Agents for the Applicant

Date March 31, 2003.

"A method and system for quality of service optimisation in a data network"

The present invention relates to a method of estimating the optimum service rate at a specified quality of service for the transmission of packets of data of different characteristics through a switch node comprising a buffer having a defined size. The invention is also directed towards a system for carrying out such a method.

Traffic in a data network is essentially composed of individual transactions or flows which can be broadly categorised as "inelastic" or "elastic". Inelastic traffic applications are those which cannot tolerate a significant delay variation in the data network. Examples of inelastic traffic flows are real time video and/or voice applications. Elastic traffic flow applications, in contrast, are those which are relatively tolerant of delay variations within the data network. Examples of elastic traffic flows include electronic mail and file transfer. The term "data network" in this specification is to be used generally as to comprise any computer network or telecommunications technology that transfers electronic data to and from user end systems in the network.

In the following discussion the terminology is that used in High-Performance Communication Networks [Jean Walrand and Pravin Varaiya (Second Edition) Academic Press 2000].

The principal network elements are links and switches. A link transfers a stream of bits from the one end to the other at a fixed rate called the link rate. Links are unidirectional. The most important links are optical fibre, copper coaxial cable and microwave "wireless" links. Link rate is often referred to as bandwidth. Several incoming and outgoing links terminate in a switch, a device that transfers bits from its incoming links to its outgoing links. A switch may be equipped with one or more buffers. A buffer is a device capable of storing bits.

When we view a network as an interconnection of network elements, we may represent the network schematically as a graph composed of nodes and edges. The nodes represent users (source or destination) or switches. The edges represent links. This can be shown as large circles representing nodes and small circles representing

users all connected by lines.

Typically, users transmit bits in bursts: active periods are interspersed with periods of inactivity. The peak rate of transmission cannot exceed the link rate. The mean rate of transmission, by definition, cannot exceed the peak rate. The ratio:

$$\frac{\text{(peak rate)} - \text{(mean rate)}}{\text{(mean rate)}}$$

is a measure of the burstiness of the source.

Typically, the internal architecture of a switch is highly complex, involving a multiplicity of buffers and scheduling mechanisms. For example with a single buffer fed by a single source the outgoing link rate is the service rate S. The buffer has a fixed size b. The service rate S is configurable. If the mean rate of transmission of bits by the source exceeds the service rate, then there will be unbounded loss of data arising from buffer overflow. After some time, the buffer will be permanently full and arriving bits will be dropped.

On the other hand, if the peak rate is less than the service rate, then the buffer will be permanently empty: each bit will be removed from the buffer as soon as it arrives. The purpose of the buffer is to deal with the intermediate situation where the service rate lies between the mean rate and the peak rate of the source.

In this intermediate situation, a queue may form in the buffer. If the queue fills the buffer, bits will be lost by buffer-overflow. If long queues form, some bits will be delayed for an unacceptably long time. The problem facing network operators is how to determine a service rate that keeps loss and delay within acceptable bounds; these bounds are known as Quality-of-Service (QoS) targets. They are expressed statistically. For example, one might require that, within a specified period, not more than 1 in 10^5 bits are lost or that not more than 1 in 10^3 buts are delayed for more than 30 milliseconds.

Since link rate is often a scarce resource, it is important to know the minimum service

rate required to meet the target QoS in a buffer of specified size. This is called the Bandwidth Requirement (BWR) of the system consisting of a source transmitting a stream of bits to a buffer. The BWR of a system depends not only on the buffer size and the QoS target but also on the statistical properties of the stream of bits; these include the mean rate and the burstiness.

Prior Art disclosed, for example in Duffield, Lewis et al. [IEEE Journal for Selected Areas in Communications, August 1995] shows that the relevant statistical data required for the determination of BWR can be encapsulated in a single function, The Scaled Cumulant Generating Function [sCGF]. An invention disclosed in PCT Publication No. WO 98/37708 TELIA et al., discloses a method and system for estimating the sCGF online in real time and storing it as a compact traffic descriptor.

Given the buffer size b and the QoS target Q, the BWR of the system can be calculated from the traffic descriptor C.

In the Prior Art, as described, the source operates independently of the switch. The internet uses two different transport layers: User Data Protocol (UDP) and Transmission Control Protocol (TCP). UDP is useful for inelastic traffic such as telephony over the internet and audio and video streaming applications. In UDP, the source operates independently of the switch and the method described above applies.

TCP is designed to give guaranteed service delivery without duplication. It is used for elastic traffic involving transactions between client and server such as the downloading of web pages, for example. It involves the use of flow control in which the source receives feedback from a switch. A consequence of this is that the behaviour of the source becomes dependent on the service rate at the switch.

US Patent Specification No. 6,266,322 B1 (AT&T Corp) which is specifically referenced in totality herein describes in some detail how elastic data traffic is handled.

Indeed this US patent specification discloses a method of dimensioning link bandwidth for elastic data traffic for a link in a communications network. This US patent discloses a method for allocating a bandwidth for a link of elastic data traffic flow. However, this

US patent does not disclose a method of accurately determining the minimum service rate to maintain quality of service requirements within the network. Further it does not address the problem of selecting an optimum service rate.

The fundamental problem in providing quality of service in a data network is to determine accurately the optimum which is in effect the minimum service rate at which packets of data are removed from a buffer in a router, whilst maintaining quality of service in the data network and optimising the available bandwidth in the network. In practice, data network operators use trial and error methods in setting the service rate to achieve the desired response time for delivering elastic traffic. This is costly and time consuming as it requires network operators to continually monitor the response time and reconfigure the service rate.

PCT Publication No. WO 01/13557 (Fujitsu Network Communications, Inc.) discloses a system for supporting multiple application traffic types over a connection network, for example, elastic and inelastic traffic. Further examples of patents in the area of handling elastic traffic in data networks are disclosed by US Patent No. 6,115,359 (Nortel Networks Corporation) and PCT Publication No. WO 01/28167 (Telefonaktiebolaget LM Ericsson).

The present invention is directed towards providing a method of estimating the optimum service rate at a specified quality of service for the transmission of data of different characteristics through a switch node comprising a buffer having a defined size. It is also necessary to do this automatically without the use of human intervention.

__Statements of Invention__

According to the invention there is provided a method of estimating the optimum service rate at a specified quality of service for the transmission of packets of data of different characteristics through a switch node comprising a buffer having a defined size, comprising the initial steps of:-

setting the target quality of service (QoS);

determining the size of the buffer (b);

providing a descriptor (C) for the traffic being transmitted to allow the calculation of the estimated bandwidth requirement (BWR) for that traffic; and

then, at time intervals, carrying out the steps of:-

(a) sampling the traffic;

(b) extracting the descriptor;

(c) configuring a service rate;

(d) calculating from the descriptor the BWR for the configured service rate;

(e) using the calculated BWR to define a new configured service rate;

(f) iteratively carrying out steps (d) and (e) until the calculated BWR and the configured service rate coincide; and

(g) defining this final service rate as the optimum service rate for that traffic at that buffer.

In one method of carrying out the invention the service rate specified in step (c) is the previous optimum service rate.

In another embodiment of the invention the traffic is continuously monitored and if the descriptor of the traffic changes, a new optimum service rate is calculated.

In another embodiment of the invention when the required target QoS over time

deviates significantly from the target quality of service initially set, the target QoS is reset.

It will be appreciated that the various steps of the method described above may be carried out in various jurisdictions and to avoid unnecessary complication of language this has not been specified in the above and this would be particularly the case with telecommunication systems to which the present invention is directed that there may for example be an end user in one jurisdiction, an end user in another jurisdiction and indeed routers, switches and the like equipment in still further jurisdictions. Thus it is to be understood that the invention covers its carrying out in more than one jurisdiction.

Further, the invention provides a closed loop control system comprising a communications network in which are interconnected:-

user end systems for the delivery and reception of data;

switch, nodes incorporating buffers;

schedulers connected to each (at least some of the buffers?) buffer to provide priority scheduling;

a programmable controller having means to carry out the method as laid out above

In the closed loop control system the controller may be directly connected to a specific end user output router.

The invention also provides a computer program comprising program instructions for causing the computer to perform the method as laid out above or indeed to provide the means used in the control system as laid out above. Such a computer program may be embodied on a record medium, a computer memory or in a read only memory or carried on an electrical carrier signal.

Detailed Description of the Invention

The invention will be more clearly understood by the following description of an embodiment thereof given by way of example only with reference to the accompanying drawings in which:

Figs. 1 to 4 are various graphs illustrating bandwidth requirement as a function of service rate.

Before discussing in detail the invention and how it is carried out it is advantageous to state a few simple facts regarding quality of service and effective bandwidth and bandwidth requirements. The bandwidth requirement for any particular level of service ((B(S)) is dependent on three factors. The first factor is the quality of service (QoS) that you require which may for example in the transmission of elastic data be described as the number of packets dropped i.e. those that have to be resent. In other words they are not accepted at a particular buffer and must be resent by the source. Typically as explained above, 1 in 10^5 packets dropped or alternatively that 1 in 10^3 packets are not delayed by more than 30 milliseconds are often considered acceptable.

The second factor is the size of the buffer which is preconfigured. The third factor that effects the bandwidth requirements is effectively the nature of the actual data being transmitted. This as already explained, can be described statistically and there are various methods of providing a descriptor of that data which descriptor relates to certain statistical properties of the data being transmitted. Accordingly therefore one can state.......

B(C): = BWR (C, b, Q)

Where C – the characteristic of the traffic
b – buffer size
Q – Quality of Service

As already discussed and explained above, for an elastic traffic source, one can no

longer assume that the traffic descriptor of the source is independent of the service rate at the buffer. Consequently the BWR as we have described it become a function of the service rate S. We denote the BWR for fixed buffer size and fixed QoS target by B(S) as illustrated in Fig. 1.

The present invention is based on a simple empirical discovery that for small values of service rate i.e. for small values of S the bandwidth requirement for that service rate will be greater than the service rate and that for large service rates the bandwidth requirement will be less than the service rate. Furthermore, the bandwidth requirement increases as S increases.

Thus we have observed that, for elastic traffic sources, B(S) increases continuously as S increases. Furthermore, we have observed that, for small values of s, B(S) is greater than S, for large values of S, B(S) is less than S see Fig. 2.

Referring now to Fig. 2 what we do know about traffic is that the bandwidth requirement for a particular level of service is somewhat as shown. We know that the bandwidth requirement will look somewhat like the graph drawn but in every case we do not know exactly what it is. However at the specific point S^* in Fig. 2 the bandwidth requirement is equal to the service rate from that particular size.

It follows that, for an elastic source, the Optimum Service Rate is the unique value S^* for which S=B(S). Hence any method of solving iteratively the equation S=B(S) yields a method for determining S^*. In this specification one method for solving the equation iteratively and hence determining S^* is described. The method does not rely on first determining the function B(S).

Assume the buffer size b to be known.
Fix the QoS target Q.
Configure the service rate at some initial value S_1
Estimate the traffic descriptor for the source and use it together with the values b and Q to determine the BWR value $B_1 := B(S_1)$ see Fig. 3.

Next configure the service rate to be S_2 given by $S_2=B_1$ see Fig. 4.

Repeating the procedure, we use the scheme:

For n= 1, 2,..............
Put $S_{n+1} = B_n$

to get a sequence S_1, S_2,.......

As $_n$ increases, S_n converges to S^*.

It will be appreciated that if $S_1 < B(S_1)$, the sequence increases to S^*; if $S_1>B(S_1)$, the sequence decreases to S^*.

In practice, the process is continued indefinitely. In the event of the source changing other than in response to the service rate (for example, changing the software package that is running) a new function B(S) becomes operative.

The method here discloses has the property that the service rate sequence will converge to S^*, the solution of the equation $S = B(S)$.

Essentially by calculating the estimated bandwidth requirement for the particular service rate it is possible to iteratively find the optimum service rate namely the minimum service rate to handle that particular traffic.

You start the operation with a service rate S_1 and then determine by online measurement the traffic descriptor of the source. This is done for a specified size of buffer and quality of service required. Then you calculate the bandwidth requirement B_1. You reconfigure the service rate to be S_2 given by $S_2 = B_1$. Repeating this process iteratively you obtain a sequence S_1, S_2,...... of service rates that converges to the optimal service rate S^*. In practice, the service rates S_1, S_2..... are reconfigured at regular time intervals such as for example 5 minutes.

It also has to be appreciated that in many instances it will be necessary to carry out the

operation indefinitely. A reason for this would be for example where the software packages or operations being run are changed. In which case, the bandwidth requirement function changes and the method ensures that the service rate converges to the optimal value corresponding to the new bandwidth function.

It will be appreciated that the invention can be carried out in many jurisdictions and that therefore it would not be unreasonable to find that certain operations are carried out in one country and more carried out another.

It is envisaged that there are many ways that the invention may be carried out by computers and similar equipment suitably programmed. Further the information and data generally supplied will allow many and varied control operations to be carried out using the invention.

Essentially what the present invention does is provide packet level quality of service on a data network where the rate at which a source emits data packets adapts to utilise all the available bandwidth. The present invention determines accurately the minimum service rate which is obviously the optimum service rate required to achieve a target level of service. For example in the remote querying of a database, the application level response time increases with an increase in packet delay caused by the queuing of packets in the buffer at a network element. As has been explained above, in order to achieve acceptable response times ways must be found to achieve a quality of service target expressed as delay restraints. Present systems do not allow this.

The present invention provides a way of directly controlling packet level quality of service. Essentially the present invention is "lightweight" and capable of being incorporated in closed loop control systems as described with reference to Fig. 4 will allow the automation of the operation and avoids manpower intensive operations now required in changing the provisioning in a system with changing traffic patterns.

In this specification the terms "comprise, comprises, comprised and comprising" and any variation thereof and the terms "include, includes, included and including" and any variation thereof are deemed to be totally interchangeable and should be afforded the widest interpretation possible.

This invention is in no way limited to the embodiment shown and may be varied in both construction and detail within the scope of the claims.

CLAIMS

1. A method of estimating the optimum service rate at a specified quality of service for the transmission of packets of data of different characteristics through a switch node comprising a buffer having a defined size, comprising the initial steps of:-

setting the target quality of service (QoS);

determining the size of the buffer (b);

providing a descriptor (C) for the traffic being transmitted to allow the calculation of the estimated bandwidth requirement (BWR) for that traffic; and

then, at time intervals, carrying out the steps of:-

(a) sampling the traffic;

(b) extracting the descriptor;

(c) configuring a service rate;

(d) calculating from the descriptor the BWR for the configured service rate;

(e) using the calculated BWR to define a new configured service rate;

(f) iteratively carrying out steps (d) and (e) until the calculated BWR and the configured service rate coincide; and

(g) defining this final service rate as the optimum service rate for that traffic at that buffer.

2. A method as claimed in claim 1, in which the service rate specified in step (c) is the previous optimum service rate.

3. A method as claimed in claim 1 or 2, in which the traffic is continuously monitored and if the descriptor of the traffic changes, a new optimum service rate is calculated.

4. A method as claimed in any preceding claim, in which when the required target QoS over time deviates significantly from the target quality of service initially set, the target QoS is reset.

5. A method as claimed in any preceding claim, in which the steps of the method are carried out in more than one jurisdiction.

6. A closed loop control system comprising a communications network in which are interconnected:-

user end systems for the delivery and reception of data;

switch, nodes incorporating buffers;

schedulers connected to each (at least some of the buffers?) buffer to provide priority scheduling;

a programmable controller having means to carry out the method of any preceding claim.

7. A closed loop control system as claimed in claim 6, in which the controller is directly connected to a specific end user output router.

8. A computer program comprising program instructions for causing a computer to perform the method of claims 1 to 5 inclusive.

9. A computer program comprising program instructions for causing a computer to provide the means of claims 6 or 7 inclusive.

10. A computer program as claimed in claim 8 or 9 embodied on a record medium.

11. A computer program as claimed in claim 8 or 9, embodied in a computer memory.

12. A computer program as claimed in claim 8 or 9, embodied in a read-only memory.

13. A computer program as claimed in claim 8 or 9, carried on an electrical carrier signal.

Graph of the curve $y = B(S)$

Fig. 1.

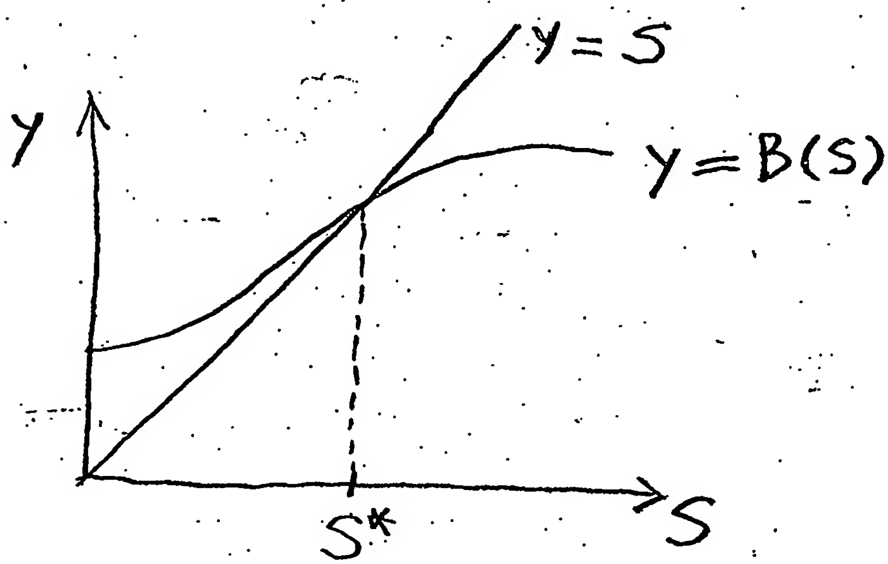

Fig. 2.

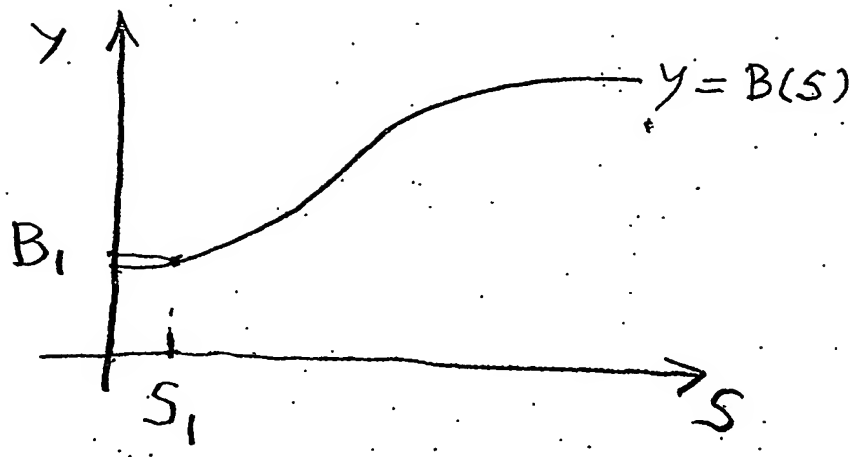

Fig. 3.

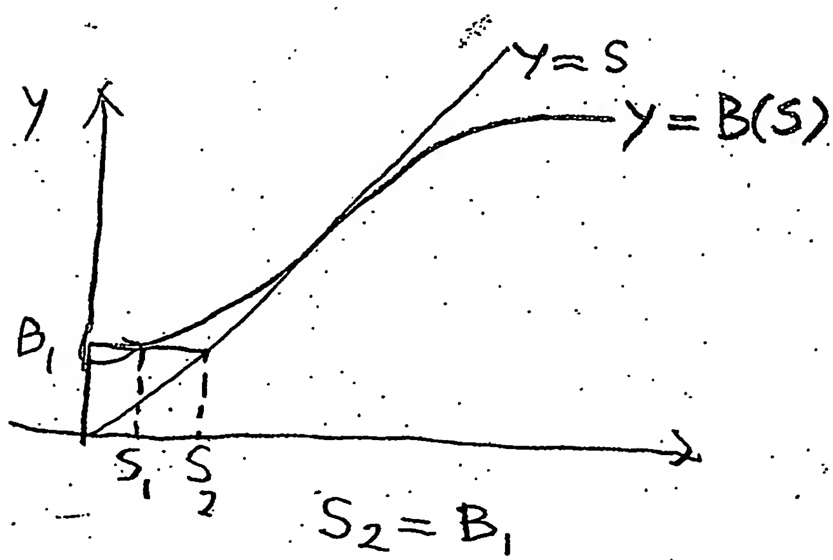

Fig. 4.

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